Sierra Nevada Network
Vital Signs Monitoring Plan

Appendix C: Air Quality Synthesis

Natural Resource Report NPS/SIEN/NRR—2008/072

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General Description of Air Pollution

Air pollution is currently recognized as one of the most significant threats to natural resources of the Sierra Nevada. A description of these threats can be found in the main body of this Monitoring Plan (section 1.9.5).

Sources of air pollutants are local, regional, and in some instances, global. The National Park Service (NPS), in cooperation with state and other federal agencies, is making concerted efforts to reduce resource damage caused by air pollution. This is done by an intensive monitoring program, support for research, identifying and seizing opportunities to participate in decisions being made by regulatory groups, and expanding the education of park visitors and those concerned about the future of Sierra Nevada parks.

Kings Canyon, Sequoia, and Yosemite National Parks are designated Class I air sheds under the Clean Air Act (1977 amendment). As such, the parks are afforded the greatest degree of air quality protection under the Clean Air Act, and the National Park Service is required to do all it can to ensure that air quality related values are not adversely affected by air pollutants. This includes participation in the review of permits of those sources whose emissions will potentially affect the parks. Devils Postpile National Monument, the fourth NPS unit in the Sierra Nevada Network (SIEN), is listed as a Class II air shed, which still has a mandate to protect air quality, but it is not as stringent as that required for parks with Class I air sheds.

Air pollution impairs visibility and injures plant and animal life. The once vast panoramas from vista points in the parks looking westward are now highly obscured by regional haze. Plant species differ in their sensitivity to pollutants; there are numerous species within SIEN parks that are damaged by air pollutants. For example, studies have shown that Jeffrey and ponderosa pines are especially sensitive to ozone (Duriscoe and Stolte 1989). Ozone-related effects include foliar damage, reduced needle retention, and reduced growth. Giant sequoia seedlings show needle damage at current ozone levels. Acid deposition has been found to affect the chemical composition of lakes and streams within the parks, which can harm aquatic life. Contaminants used in the nearby San Joaquin Valley are found in rain and snow samples within the parks, raising concern over potential impacts to both aquatic and terrestrial wildlife.

The San Joaquin Valley, west of the Sierra Nevada parks, is a trap for air pollutants originating in the Valley as well as from pollutants from cities along the central California coast. These pollutants are carried in prevailing winds. Southward wind patterns carry pollutants through the Valley until reaching the mountains (Tehachapi Range) at the southern end of the basin, causing an eddy of air to form in the vicinity of Visalia and Fresno, just west of the southern Sierra Nevada. Frequent inversions trap the Valley air at night. Rising daytime air currents subsequently carry these trapped pollutants into the Sierra Nevada, resulting in some of the worst air quality found in any NPS unit in the country (Cahill et al.1996). This movement of polluted air into the Sierra occurs daily during summer months. The airflow pattern transports air pollutants to all the SIEN parks; the highest pollutant levels occur in Sequoia and Kings Canyon—lower, but not insignificant, levels occur in Yosemite and Devils Postpile.

Automobiles are one of the major sources of pollutants in the San Joaquin Valley, contributing much of the particulates, carbon monoxide, nitrogen oxides, and hydrocarbons annually emitted. The latter two constituents are precursors in the formation of ozone. Other sources of pollution include agricultural activities (e.g., plowing, diesel generators, off-road vehicles), power generation, petroleum production, and other industrial emissions.

Emissions within the parks include motorized vehicles, whose numbers are greatest in the summer when visitation is at its highest. Smoke emissions are another source found within park boundaries. Fires from prescribed burns, wildfires, and campfires all produce varying levels of particulate matter and chemical precursors to ozone with varying but largely localized air quality impacts. During winter months, most in-park emissions are from wood used for heating; however, emissions are typically minimal due to low visitation and a smaller number of in-park residents. Still, a vast majority of air pollutants found in the parks are generated outside park boundaries.

There are also air-related health concerns in SIEN parks. Increased levels of ozone and particulate matter pose a threat to human health. The U.S. Environmental Protection Agency (USEPA) has established National Ambient Air Quality Standards (NAAQS) for each of six "criteria" pollutants, to protect the public from the health hazards associated with air pollution. These six criteria pollutants are: carbon monoxide (CO), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulate matter less than 10 micrometers ns in diameter (PM10), particulate matter less than 2.5 micrometers, and lead (Pb) (Table C-1). The state of California has adopted additional air quality standards for sulfates, hydrogen sulfide, vinyl chloride, and visibility-reducing particulates. Ozone may pose a risk to animal health as well.

Table C-1. National and California Ambient Air Quality Standards

POLLUTANT	AVERAGING TIME	FEDERAL PRIMARY STANDARDS	CALIFORNIA STANDARDS
PARTICULATE MATTER (PM10)			
	Annual Arithmetic Mean	50 ug/m3	20 ug/m3
	Annual Geometric Mean		30ug/m3
	24-hour	150 ug/m3	50 ug/m3
	1-hour	—	
PARTICULATE MATTER (PM2.5)			
	Annual Arithmetic Mean	15 ug/m3	12 ug/m3
	Annual Geometric Mean	—	
	24-hour	35 ug/m3	
	1-hour		
SULFUR DIOXIDE (SO_2)			
	Annual	80 ug/m3 (0.03ppm)	—
	24-hour	365 ug/m3 (0.14 ppm)	105 ug/m3 (0.04 ppm)
	3-hour		
	1-hour	—	655 ug/m3 (0.25 ppm)
NITROGEN DIOXIDE (NO_2)			
	Annual	100 ug/m3 (0.053 ppm)	—
	1-hour	—	470 ug/m3 (0.25 ppm)
OZONE (O_3)			
	8-hour	0.08 ppm	—
	1-hour	0.12 ppm (235 ug/m3)	0.09 ppm (180 ug/m3)
CARBON MONOXIDE (CO)			
	8-hour	9 ppm (10 mg/m3)	9.0 ppm (10 ug/m3)
	1-hour	35 ppm (40 mg/m3)	20 ppm (23 ug/m3)
SULFATES			
	24-hour	—	25 ug/m3
LEAD			
	Calendar Quarter	1.5 ug/m3	—
	30-day average	—	1.5 ug/m3
HYDROGEN SULFIDE			
	1-hour	—	0.03 ppm (42 ug/m3)
VINYL CHLORIDE (CHLOROETHENE)			
	24-hour	—	0.010 ppm (26 ug/m3)

ug/m3 = micrograms per cubic meter
ppm = parts per million
--- = no standard exists for that pollutant and/or averaging time

Criteria Pollutants: Description and Issues

Air pollutants which are determined to have a detrimental effect on human health are called criteria pollutants.

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless and poisonous gas produced by incomplete burning of carbon in fuels. When CO enters the bloodstream, it reduces the delivery of oxygen to the body's organs and tissues. Health threats are most serious for those who suffer from cardiovascular disease, particularly those with angina or peripheral vascular disease. Exposure to elevated CO levels can cause impairment of visual perception, manual dexterity, learning ability, and performance of complex tasks.

Seventy-seven percent of the nationwide CO emissions are from transportation sources. The largest emissions contribution comes from highway motor vehicles. Thus, focus of CO monitoring has been on traffic-oriented sites in urban areas where the main source of CO is motor vehicle exhaust. Other major CO sources are wood-burning stoves, incinerators and industrial sources. The National Ambient Air Quality Standard (NAAQS) for carbon monoxide is a 9 ppm, eight-hour, non-overlapping average, not to be exceeded more than once per year. An area meets the carbon monoxide NAAQS if no more than one eight-hour value per year exceeds the 9 ppm threshold. To be in attainment, an area must: (1) meet the NAAQS for two consecutive years, and (2) carry out air quality monitoring during this entire time period. Air quality carbon monoxide value is estimated using EPA guidance for calculating design values (Laxton Memorandum, June 18, 1990).

Nitrogen Dioxide

Nitrogen dioxide (NO_2) is a brownish gas produced by high-temperature combustion that is present at elevated levels in all urban environments. At very high concentrations that occur only in the most severely polluted urban areas, NO_2 can irritate lungs, cause bronchitis and pneumonia, and lower resistance to respiratory infections. More commonly, nitrogen oxides become an important precursor both to ozone (O_3), acid rain, and nitrogen deposition, and affecting the ecology of both terrestrial and aquatic ecosystems.

The major mechanism for the formation of NO_2 in the atmosphere is the oxidation of the primary air pollutant nitric oxide (NO). Both of these oxides of nitrogen (or NOx) play a major role–together with volatile organic compounds (VOCs)–in atmospheric reactions that produce O_3 and PM2.5 (PM = particulate matter). NOx forms during any high temperature combustion. The two major emissions sources are transportation (i.e., cars and trucks) and stationary fuel-combustion sources, such as electric utility and industry boilers.

Ozone

Ozone (O_3) is a photochemical oxidant and the major component of smog. While O_3 in upper atmosphere is beneficial to life by shielding earth from harmful ultraviolet radiation from the sun, high concentrations of O_3 at ground level are a major health and environmental concern. O_3 is not emitted directly into the air, but is formed through complex chemical reactions between precursor emissions of volatile organic compounds (VOC) and oxides of nitrogen (NOx) in the presence of sunlight. These reactions are stimulated by sunlight and temperature, so peak O_3 levels occur typically during the warmest, sunniest times of the year.

Both VOCs and NOx are emitted by transportation and industrial sources. VOCs are emitted from sources as diverse as autos, chemical manufacturing, dry cleaners, paint shops and other sources that use solvents. The reactivity of O_3 causes health problems because it damages lung tissue, reduces lung function, and sensitizes the lungs to other irritants. Scientific evidence indicates that ambient levels of O_3 not only affect people with impaired respiratory systems, such as asthmatics, but healthy adults and children as well. Exposure to O_3 for several hours at relatively low concentrations has been found to significantly reduce lung function and induce respiratory inflammation in normal, healthy people during exercise. This decrease in lung function is generally accompanied by symptoms including chest pain, coughing, sneezing, and pulmonary congestion.

Particulate Matter

Air pollutants called particulate matter include dust, dirt, soot, smoke, and liquid droplets directly emitted into the air by sources such as factories, power plants, cars, construction activity, fires, and natural windblown dust. Particles formed in the atmosphere by condensation or the transformation of emitted gases such as sulfur dioxide (SO_2) and VOCs are also considered particulate matter. Another byproduct of atmospheric reactions is nitric acid (HNO_3), which combines with ammonia (NH_3) to produce a species of particulate matter (PM2.5) called ammonium nitrate (NH_4NO_3) .

Based on studies of human populations exposed to high concentrations of particles (sometimes in the presence of SO_2) and laboratory studies of animals and humans, there are major effects of concern for human health. These include effects on breathing and respiratory symptoms, aggravation of existing respiratory and cardiovascular disease, alterations in the body's defense systems against foreign materials, damage to lung tissue, carcinogenesis, and premature death. The major subgroups of the population that appear to be most sensitive to the effects of particulate matter include individuals with chronic obstructive pulmonary or cardiovascular disease or influenza, asthmatics, the elderly, and children. Particulate matter also soils and damages materials, and is a major cause of visibility impairment in the United States.

Annual and 24-hour National Ambient Air Quality Standards (NAAQS) for particulate matter were first set in 1971. Total suspended particulate (TSP) was the first indicator used to represent suspended particles in the ambient air. Since July of 1987, however, EPA has used–as an indicator–those particles with aerodynamic diameter smaller than 10 micrometers. Most recently, studies have found that even smaller diameter particles (less than 2.5 micrometers or PM2.5) are an even better indicator of health effects. These smaller particles are likely responsible for most adverse health effects from particulate matter because of their ability to infiltrate the thoracic or lower regions of the respiratory tract, and even pass through the alveolar tissue into the bloodstream.

Sulfur Dioxide

High concentrations of sulfur dioxide (SO_2) affect breathing and may aggravate existing respiratory and cardiovascular disease. Sensitive populations include asthmatics, individuals with bronchitis or emphysema, children, and the elderly. SO_2 is also a primary contributor to acid deposition, or acid rain, which causes acidification of lakes and streams and can damage trees, crops, historic buildings, statues, etcetera. In addition, sulfur compounds in the air contribute to visibility impairment in large parts of the country. This is especially noticeable in national parks.

Ambient SO_2 results largely from stationary sources such as coal and oil combustion, steel mills, refineries, pulp and paper mills and from nonferrous smelters. There are three NAAQS for SO_2: an annual arithmetic mean of 0.03 ppm (80 ug/m3); a 24-hour level of 0.14 ppm (365 ug/m3); and a 3-hour level of 0.50 ppm (1300 ug/m3). The first two standards are primary (health-related) standards, while the 3-hour NAAQS is a secondary (welfare-related) standard. The annual mean standard is not to be exceeded, while the short-term standards are not to be exceeded more than once per year.

Attainment

To reiterate, air pollutants determined to have a detrimental effect on human health are called criteria pollutants. Geographic areas are determined, by both national and California standards, as meeting or not meeting the health based standard for a specific air pollutant (e.g., ozone, PM10). An area may be in attainment for one pollutant and non-attainment area for others. The following tables describe attainment status for Sierra Nevada Network parks (Table C-2). Non-attainment status requires that the area produce a plan, with a targeted

Table C-2. Attainment status for criteria air pollutants in SIEN parks: Yosemite (YOSE)–Mountain Counties (Mariposa and Tuolumne) Air District; Sequoia & Kings Canyon National Parks (SEKI) and Devils Postpile National Monument (DEPO)–San Joaquin Valley Air District.

POLLUTANT	FEDERAL	STATE
YOSEMITE		
O_3 (1hr)	Attainment	Non-Attainment
O_3 (8hr)	Non-Attainment	—
CO	Attainment	Unclassifiable
PM10	Attainment	Non-Attainment
PM2.5	—	Unclassifiable
SO_2	Attainment	Attainment
NO_2	Attainment	Attainment
SEQUOIA & KINGS CANYON AND DEVILS POSTPILE		
O_3 (1hr)	Non-Attainment/Extreme	Non-Attainment
O_3 (8hr)	Non-Attainment/Serious	—
CO	Attainment	Attainment
PM10	Non-Attainment/Serious	Non-Attainment
PM2.5	—	Non-Attainment
SO_2	Attainment	Attainment
NO_2	Attainment	Attainment

Table C-3. Target dates for attainment (as of 17 May 2004).

AIR DISTRICT	POLLUTANT	AVERAGING TIME	CLASSIFICATION	ATTAINMENT YEAR
SAN JOAQUIN VALLEY	Ozone	1-hour	Extreme	2010
	Ozone	8-hour	Serious	2013
	Particulate Matter (PM10)			
MARIPOSA/ TUOLUMNE	Ozone	1-hour	***	***
	Ozone	8-hour	Subpart 1	2009
	Particulate Matter (PM10)			

***no data available and/or no attainment classification

timeline, to reduce pollutant levels within the specified area and submit the plan to the appropriate level of government (state or federal) for approval.

Air Quality in Sierra Nevada Parks

Emissions

Devils Postpile and Sequoia and Kings Canyon are located within the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD). The SJVUAPCD is made up of eight counties (San Joaquin, Stanislaus, Merced, Madera, Fresno, Tulare, Kings, and Kern) in the San Joaquin Valley. This air district is in non-attainment status for ozone and PM10 (Table C-2).

Yosemite lies within Mountain Counties' air district, comprising Tuolumne and Mariposa Counties. A small portion of southern YOSE is located in Madera County but the park is generally not regulated by the SJVUAPCD. Mountain Counties Air District also has non-attainment status for ozone and PM10 (Table C-2).

All SIEN parks are exposed to pollutants transported from the Valley as well as from other urban areas of California due to prevailing westerly winds. Approximately nine percent of the state's thirty five million people live in San Joaquin Valley (SJV), and emission sources (e.g., industry, agriculture, and transportation) within SJV account for about 14 percent of total statewide emissions (Alexis et al. 1999).

Emissions in SJV derive from a number of moderate-sized urban areas, primarily located along the Highway 99 corridor. The other main travel corridor in SJV is US Interstate 5. Since 1980, population growth in the SJV has been more rapid than in other parts of California, partially offsetting effects of emission-control programs (Alexis et al. 1999). Air pollution sources found within parks include: automobiles, buses, construction activities, campfires, wood-burning stoves, natural and prescribed fire, and road dust.

Principal air pollutant species of concern to SIEN parks are ozone, ozone precursors (NOx and VOC's), particulate matter precursors, and particulate matter concentrations that decrease visibility and/or lead to acidic deposition. SO_2 emissions are not high in any SIEN parks. Air districts' target dates for ozone and PM10 standards attainment are shown in Table C-3.

Sequoia and Kings Canyon are located within Fresno and Tulare counties. No major point sources of emissions are located in Tulare County; major point sources are not numerous in Fresno County, nor in most other counties of the SJV. Within Fresno County, the closest sources that emit at least 100 tons/year of VOC, NOx, PM10, or SO_2 are located near Fresno and Kingsburg; three additional point sources are located in the western portion of the county. As of 1996, stationary sources accounted for 22% of ROG emissions, 34% of NOx emissions, and 4% of PM10 emissions in Fresno County (CARB, 1998b). In Tulare County, stationary sources accounted for 8% of ROG emissions, 11% of NOx emissions, and 5% of PM10 emissions in1996 (CARB, 1998b). In both Fresno and Tulare counties, mobile sources dominated NOx emissions, while area sources (road dust, construction, and farming operations) dominated PM emissions. Mobile sources accounted for 46% of VOC emissions in Fresno and 41% in Tulare Counties.

Yosemite is located within Madera, Mariposa, and Tuolumne counties. Major point sources are not numerous in these counties, nor in most other counties of the SJV or Mountain Counties air basins. Sources that emit at least 100 tons/yr of VOC, NOx, PM10, or SO_2 are located near Jamestown and Standard in Tuolumne County, and farther away, near Madera and Chowchilla in western Madera County; none are located within Mariposa County. As of 1996, stationary sources accounted for 12% of VOC emissions, 36% of NOx emissions, and 7% of PM10 emissions in Madera, Mariposa, and Tuolumne counties (CARB1998b). Mobile sources dominated NOx emissions, whereas area sources (road dust, construction, and farming operations) dominated PM emissions.

Devils Postpile is, technically, in SJVUAPCD, but is located at the extreme eastern edge of Madera County. It straddles the San Joaquin Valley (SJV) and Great Basin (GB) Air Basins. There are significant differences between the two air basins. One is size: the SJV is larger, comprising eight counties; the GB comprises three counties. We are concerned with both ozone and particulate matter in SJV; in GB, particulate matter is more prominent. Area wide sources are the main contributor of PM for both districts. Mobile sources are the most influential in contributing precursors of ozone in SJV. Monitoring near the monument provides air-related data that are relevant to DEPO.

Ozone

Through monitoring and research at Sequoia, Kings Canyon and Yosemite, we know that ozone levels are consistently higher than background or natural levels. All three parks experience multiple days where ozone levels exceed the state and national health standard (for 8hr ozone). While elevated levels of ozone can be found at all of the Class I SIEN parks, levels are consistently and at times substantially higher at Sequoia and Kings Canyon. For example, in 2003 Sequoia and Kings

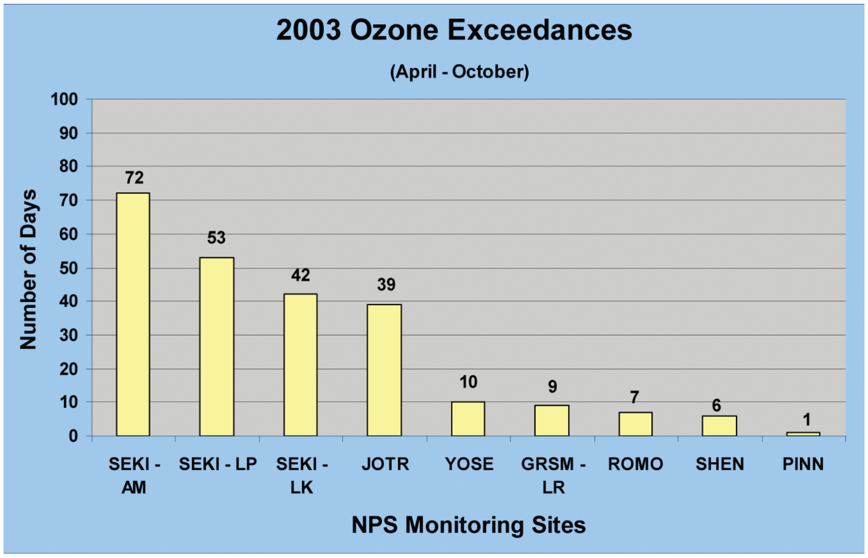


Figure C-1. Ozone Exceedance Chart

Table C-4. Bio-indicator plant species

PARK	SCIENTIFIC NAME	COMMON NAME
SEKI,YOSE	*Apocynum androsaemifolium*	Spreading dogbane
SEKI,YOSE	*Artemisia douglasiana*	Mugwort
SEKI,YOSE	*Physocarpus capitatus*	Ninebark
SEKI,YOSE	*Pinus jeffreyi*	Jeffrey pine
SEKI,YOSE	*Pinus ponderosa*	Ponderosa pine
SEKI,YOSE	*Populus tremuloides*	Quaking aspen
SEKI,YOSE	*Rhus trilobata*	Skunkbush
SEKI,YOSE	*Salix scouleriana*	Scouler's willow
SEKI,YOSE	*Sambucus mexicana*	Blue elderberry

Canyon exceeded the health standard for ozone (85 ppb 8 hr. average) 72 days, while Yosemite recorded 10 days above the standard (Figure C-1). These numbers of days exceeding health standards ranks Sequoia, Kings Canyon and Yosemite in the top 10 most ozone polluted parks in the country.

Ozone is a pollutant well known for producing foliar damage in ozone sensitive ponderosa and Jeffrey pines. Ozone damages photosynthetic cells in these pines. It impairs their ability to grow, and compete with other plants, and compromises their resistance to other forest stressors such as insects, pathogens, and drought. (James 1980, Miller 1983). Monitoring sensitive vegetation for ozone damage will help define the severity of impact to our resources. Potential bio-indicator plant species, plants with sensitivity to ozone pollution for the SIEN parks are listed in Table C-4 (NPS—Air Resources Division).

Nitrogen and Sulfur Deposition

Although acidic deposition has been found to currently have less significant impact on Sierra Nevada resources, there are two seasonal pulses of acidity: (1) late summer rain, and (2) the onset of spring snowmelt. These pulses of relatively high acidity can lower pH below 5.35, making naturally basic waters acidic in an un-buffered ecosystem (i.e., not much vegetative cover, steep slopes, granite under-layer, not much soil) (Melack and Sickman et al. 1998). Recent research suggests that these high elevation systems are more resilient that originally believed (Melack and Sickman et al. 1998). Currently, these systems are able to buffer existing acidic events. Potential reactions of these systems to increased acidic deposition are not well understood. In forested ecosystems, summer wet deposition concentrations of NO_3 and SO_4 averaged two and five times higher, respectively, as compared with concentrations reported for remote areas of the world (Stohlgren and Parsons 1987).

Although we don't know the minimum concentrations of acid that may cause direct or indirect foliar damage to plant species in Sierra Nevada parks, Stohlgren and Parsons (1987) emphasized that acid concentrations are highest during the primary growing season and during periods of maximum drought stress. Both of these occur during the summer (Stohlgren and Parsons 1987; Williams and Melack 1991; Williams and Melack 1997b; Melack et al. 1998; Williams et al. 1995; Galloway et al. 1982; Stoddard 1994).

Wet deposition monitoring has provided a long term data set in Sequoia, Kings Canyon, and Yosemite, measuring constituents that are related to vehicle, agriculture, and other human activities which produce air pollutants. The data show that national parks in the West do not receive substantial amounts of wet SO4 deposition. On the other hand, levels of NO_3 and NH4 deposition appear high enough to fertilize terrestrial vegetation and cause euthrophication of aquatic systems. However, without site-specific totals or dry deposition data to accompany the wet deposition data, a quantitative (i.e., determination of critical loads) approach remains improbable. Figure C-2 illustrates approximately the past 20 years of annual deposition of NO3, NH4, and SO4 for Sequoia, Kings Canyon, and Yosemite. These numbers do not provide a complete picture of N contribution from dry deposition in the parks: given their Mediterranean climate, almost half the year is dry. Therefore wet deposition values alone underestimate total deposition.

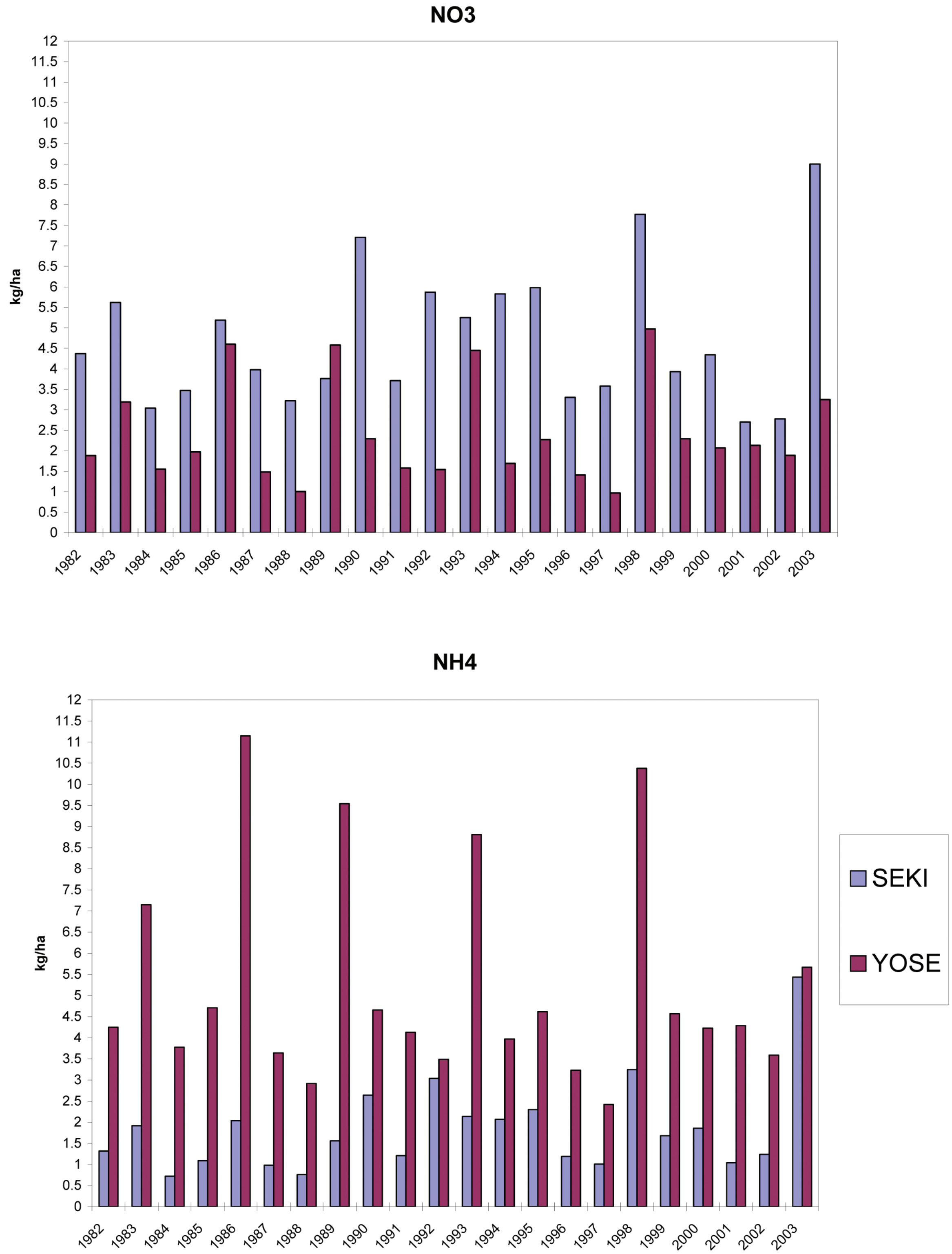


Figure C-2. Total Annual Wet Deposition (NADP), SEKI and YOSE, 1982–2003.

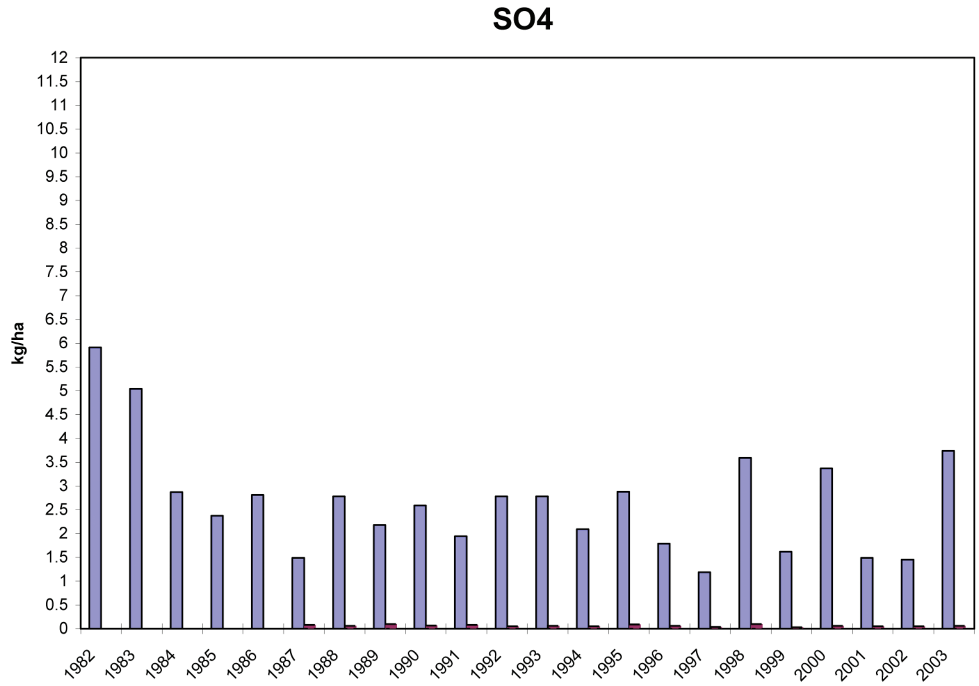


Figure C-2. Total Annual Wet Deposition (NADP), SEKI and YOSE, 1982–2003 (cont'd).

Particulate Matter/Visibility

Changes in visibility at SIEN parks are largely due to organics, sulfates, and nitrates. Historically, visibility varies with patterns in weather, winds, and smoke from fires. The cleanest 20% of days probably approaches natural conditions (GCVTC 1996). Smoke from frequent fires is suspected to have reduced pre-settlement visibility below current levels during some summer months, however there are no quantitative records for comparison to more recent datasets. Long-term visibility trends fall into three categories: increases, decreases, and insignificant changes. The characterization of long-term trends can be a highly subjective exercise: slopes and their statistical significance can vary depending on the technique employed. Recently the IMPROVE aerosol network, initiated in March 1988, matured to a point where long-term trends of average ambient aerosol concentrations and reconstructed extinction can be assessed for sites with an eleven year period of record (CA Class I Parks 2001).

Because full IMPROVE aerosol monitoring was not initiated at Yosemite or Sequoia until March 1994, the current monitoring period is not considered long enough to adequately summarize long-term trends. Seasonal trends (1996 to 1998) show that fine aerosols rise in the summer and that organics make up the largest proportion of these aerosols (see Figure C-3 and also, http://vista.circa.colostate.edu.improve/Data/GraphicViewer/).

Other aerosol species observed include: sulfate, nitrate, elemental (light absorbing) carbon, and coarse particles (i.e., wind blown dust). Coarse particles tend to have geological origins and deposit close to their source. Fine particles are usually man-made or from fires, have the ability to transport great distances, and cause the greatest impairment to visibility. Of the fine particles, the organics and carbon are largely from fires or biogenic sources, while the sulfate and nitrate are from anthropogenic sources.

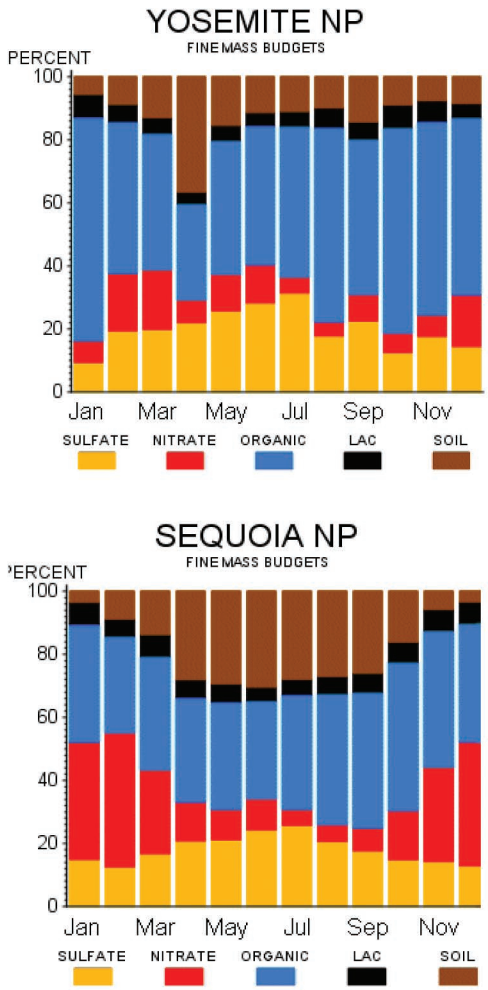


Figure C-3. Fine aerosol mass proportions for Yosemite and Sequoia National Park, 1996-1998. Light absorbing carbon noted as LAC, above.

In the Malm et al. (2000) IMPROVE report, eleven years of data were used to describe trends in particulate matter (specifically, PM2.5) pollution for Yosemite (CA Class I parks 2001). Aerosol species were associated with low, median, and high fine mass day categories, and then respective light extinctions and deciviews (relative haziness values) were calculated for each species. The report concluded that there was an insignificant change in visibility over time, meaning that there was neither an increasing nor a decreasing trend (Figure C-4). However, like Sequoia, seasonal trends within Yosemite show a significant rise in fine aerosols through the hot summer months, with organics making up the largest proportion of these aerosols—large regional fires are the most likely origin of these fine particles, although some sulfate increase has been recorded most recently (2007). Visibility diminishes with increased particulate matter pollution, so the IMPROVE network attempts to identify chemical species that significantly reduce visibility in our Parks.

By summarizing these data regionally and comparing them nationally, it becomes apparent that southern California visibility is similar to northern Massachusetts and southern Vermont in terms of average haziness in deciviews (Figure 3). However, approximately 11% of southern California's light absorption is caused by aerosols, while only 5.1% of New England's light absorption is caused by aerosols. This is a complicated observation considering the differences in average air moisture content between the two regions, as well as the variety of pollution species, all contributors to haze. The worst average visibility in the country is in the southeast, with visibility impairment values of 21 to 26 deciviews (lower numbers denote greater visibility).

Contaminants

California pesticide-use data show that between 1991 and 2000, approximately 2 billion pounds of active ingredients were applied in the State (Pesticide Action Network). Pesticides, which are used extensively in California's heavily-farmed SJV, are of concern in the Sierra Nevada. Potential impacts depend on the degree to which a particular pesticide breaks down in the environment and the levels of toxicity of the breakdown products. The amount of pesticide use suggests that further study is warranted. Pesticides vary as to their levels of volatility. For example, in Fresno County, the estimated pesticide VOC emissions potential of 17.6 million pounds (8.8 thousand tons) is a substantial portion of the total VOC emissions of 39.4 thousand tons. However, California Department of Pesticide Regulation's (CDPR) estimate of VOC emissions potential exceeds that used in the CARB emissions inventory (CARB, 1998b) by a factor of two. It also should be noted that most ozone formation in the SJV is NOx,

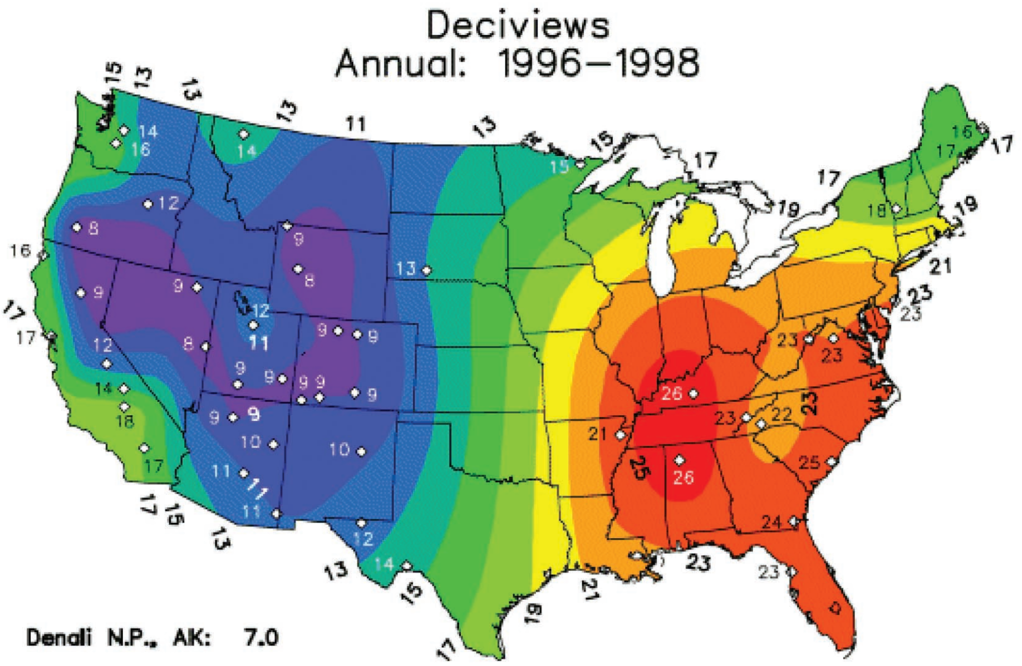


Figure C-4. Regional visibility measured in deciviews,1996 to 1998. Lower numbers denote greater visibility.

not VOC limited, so the increase from pesticides probably has little impact on actual ozone formation where that NOx limitation prevails. Some sites downwind however (i.e., in SEKI), may be less NOx limited due to degradation aging of the NOx plumes during transport (Blanchard, 2001; Luria, 1999, 2000)

Pesticides are of concern for their potential toxicity, not just their ozone-forming potential. Studies conducted in SEKI indicate that more commonly and heavily used pesticides in the SJV are transported into the Sierra Nevada (Zabik and Seiber 1993, LeNoir et al. 1999). Measurements made in Sequoia National Park, showed pesticides concentrations diminishing between Ash Mountain entrance station and Lower Kaweah (Zabik and Seiber 1993). This represents a decrease in concentration with both distance and elevation (relative to the San Joaquin valley floor). Pesticides applied to crops (that are intensively produced in the Central Valley) can volatilize under warm valley temperatures, subsequently be transported via upslope air movement, and then deposited in the cooler, high-elevation regions of Sequoia National Park (Zabik and Seiber 1993; LeNoir et al. 1999).

In 2002, SEKI was included in the Mercury Deposition Network (MDN), a network developed by the National Atmospheric Deposition Program (NADP). The sampler is co-located with the NADP sampler at Lower Kaweah in Sequoia National Park. This network investigates the local and regional transport and deposition of mercury. Mercury is known to contaminate aquatic ecosystems, and there are over 30 states which have fish consumption advisories due to mercury content. Atmospheric transport and deposition is the dominant pathway to aquatic ecosystems. This problem has greater attention in the eastern U.S., as reflected in both the number of sampling sites in the east, and mercury levels found in these states. Origin of mercury in the East is predominantly from coal burning industries. There also exists global transport of mercury in the atmosphere, whose source is wide and varied. Effects of mercury deposition vary by site as a result of differences in soil chemistry, water chemistry, the food web, etc. There is less information on mercury deposition in California, and there are only 2 active MDN sites in California.

Air Resources Division of the National Park Service

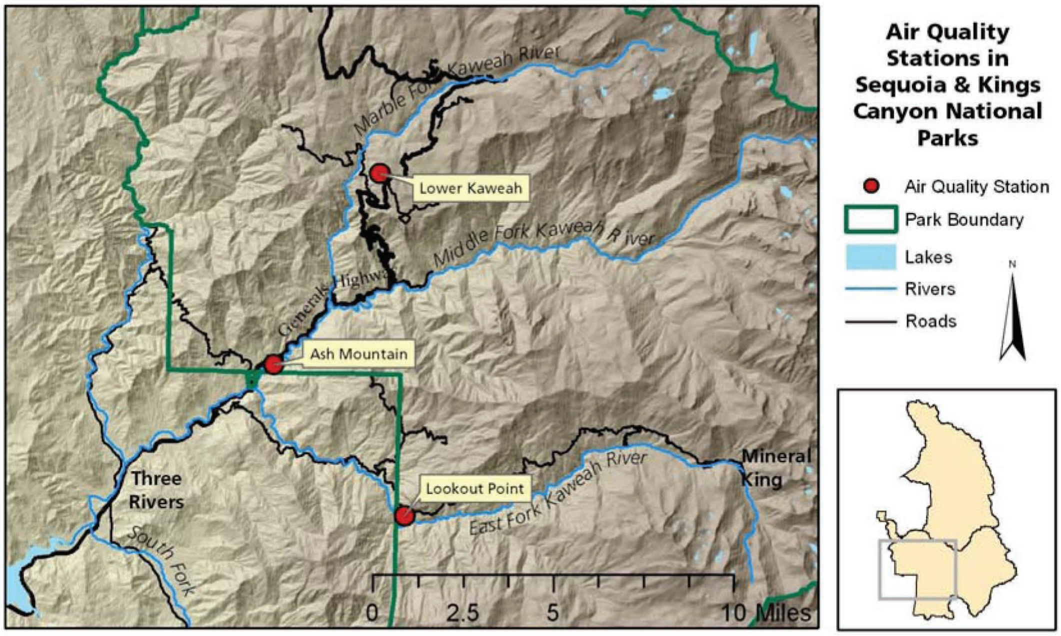
The National Park Service Air Resources Division (ARD) mission is to: "[p]reserve, protect, enhance, and understand air quality and other resources sensitive to air quality in the National Park System" (http://www2.nature.nps.gov/air/). In order to do this, a combination of both monitoring and research is necessary. Long-term monitoring data make it possible to plot and assess air pollution patterns and compare these patterns to other regions of the country. At the same time, research data are needed to answer more specific pollution questions concerning cause and effect and total deposition loads.

As part of the NPS ozone monitoring network, and by participating in the National Atmospheric Deposition Program (NADP), the Interagency Monitoring of Protected Visual Environments (IMPROVE), and the Clean Air Status & Trends Network (CASTNet), Sequoia & Kings Canyon and Yosemite National Parks contribute to the NPS effort to monitor air pollution in the form of wet deposition and dry deposition, as well as fine particulate matter and aerosols. All of these monitoring data are collected with relevant meteorological data, making the interpretation of the pollutant patterns more meaningful and comparable. Air-related research projects are mostly cooperative with the NPS in the role of facilitator, supplying information and resources to universities, private researchers, and other branches of state and federal government.

Long-term Monitoring Programs

The National Park Service Air Resource Division (ARD) coordinates NPS air quality monitoring programs nationwide and contracts with a private consulting group called Air Resources Specialists (ARS) located in Fort Collins, Colorado Specifically, ARS provides technical support which enables NPS station operators to troubleshoot complicated monitoring equipment and provide for consistent operations. Their efforts contribute to generation of accurate and high quality data. The ARS group also helps NPS-ARD with data summaries and interpretation.

Both Yosemite and Sequoia & Kings Canyon operate year-round air monitoring sites, some dating back to the early 1980s (Figure C-5). Each site is unique in its array of monitoring equipment (described in Table C-5). Devils Postpile National Monument does not currently conduct any air monitoring within the boundaries of the monument, but monitoring work has been conducted in the surrounding area and is representative of air in the monument.



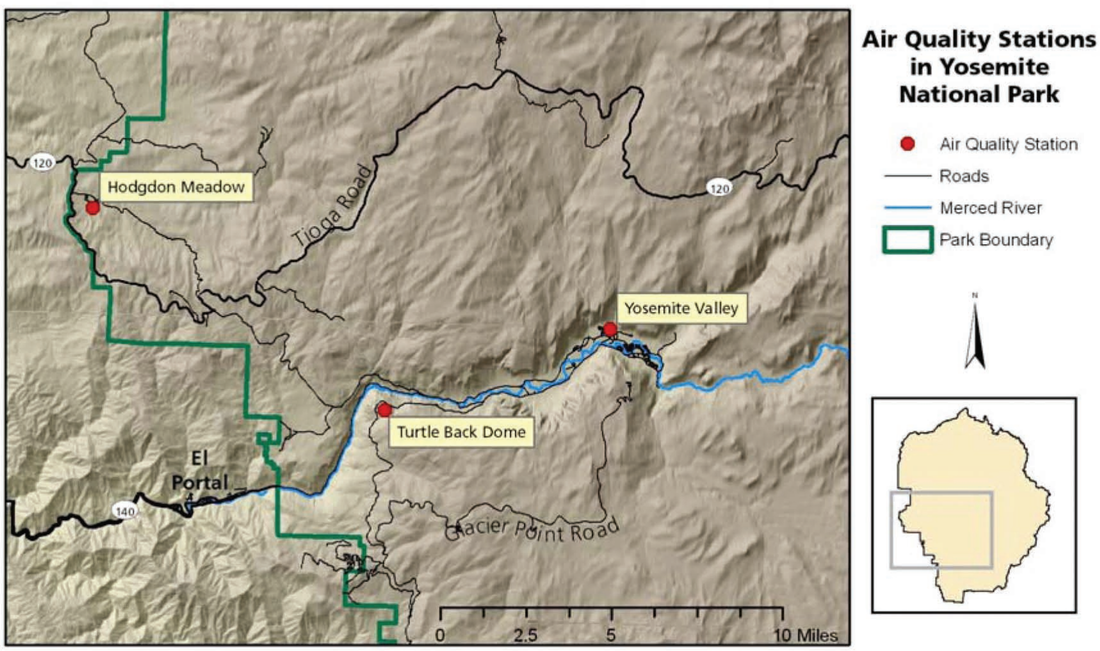


Figure C-5. Air quality monitoring sites in Sequoia & Kings Canyon and Yosemite National Parks.

Table C-5. Air monitoring stations

PARK	SITE	TYPE	NETWORK**
SEQUOIA	Ash Mountain	Meteorology	NPS – ARD
		Ozone	NPS – ARD
		Particulate Matter	SEKI Fire
		$PM_{2.5}$ and PM_{10}	IMPROVE
	Lookout Point	Meteorology	NPS – ARD
		Ozone	NPS – ARD
		Dry deposition	CASTNet
	Lower Kaweah	Meteorology	NPS – ARD
		Ozone	NPS – ARD
		Wet deposition	NADP/NTN
		Mercury	MDN
		Webcam	NPS – ARD
YOSEMITE	Yosemite Valley	PM2.5 and PM10	CARB
		Meteorology	NPS – ARD
		Ozone	NPS – ARD
		NO_X	NPS – ARD
		CO	NPS – ARD
	Turtleback Dome	Meteorology	NPS – ARD
		Ozone	NPS – ARD
		Visibility	NPS – ARD
		Webcam	YOSE Concession
		Dry deposition	CASTNet
		Particulate Matter	IMPROVE
	Hodgdon Meadow	Wet deposition	NADP/NTN

** California Air Resources Board (CARB)
Clean Air Status and Trends Network (CASTNet)
Interagency Monitoring of Protected Visual Environments (IMPROVE)
Mercury Deposition Network (MDN)
National Atmospheric Deposition Program/National Trends Network (NADP/NTN)
National Park Service – Air Resources Division (NPS-ARD)

National Atmospheric Deposition Program/National Trends Network (NADP/NTN) is a nationwide network of over 200 precipitation monitoring sites developed by the EPA. The NADP/NTN is a cooperative effort between many different groups, including the State Agricultural Experiment Stations, U.S. Geological Survey, U.S. Department of Agriculture, and numerous other governmental and private entities. Its purpose is to collect weekly rain, snow, or condensation samples and produce chemical data. The weekly water samples are sent to the Central Analytical Laboratory where they are analyzed for hydrogen (acidity as pH), sulfate, nitrate, ammonium, chloride, and base cations (such as calcium, magnesium, potassium and sodium (paraphrased from http://nadp.sws.uiuc.edu/nadpoverview.asp).

The NADP site within Giant Forest, Sequoia National Park, has been in operation since the early 1980's. The NADP site at Hodgden Meadows in Yosemite has been operating since 1981.

Interagency Monitoring of Protected Visual Environments

Interagency Monitoring of Protected Visual Environments (IMPROVE) is a cooperative measurement effort comprising representatives from federal and regional-state organizations. It aids the creation of federal and state implementation plans for the protection of visibility in Class I areas (156 national parks and wilderness areas) as stipulated in the 1977 amendments to the Clean Air Act .The objectives of IMPROVE are to:

1. Establish current visibility and aerosol conditions in mandatory class I areas
2. Identify chemical species and emission sources responsible for existing man-made visibility impairment
3. Document long-term trends for assessing progress towards the national visibility goal
4. Provide regional haze monitoring representing all visibility-protected federal class I areas where practical (in response to the enactment of the Regional Haze Rule)

IMPROVE has also been a key participant in visibility-related research, including the advancement of monitoring instrumentation, analysis techniques, visibility modeling, policy formulation and source attribution field studies (paraphrased from http://vista.circa.colostate.edu.improve/Overview/Overview.htm).

A full IMPROVE aerosol sampler (modules A, B, C, and D) began operation at Sequoia in March of 1994. The sampler is located near Park Headquarters at Ash Mountain, at the southwest entrance to Sequoia National Park. There has been a full IMPROVE aerosol sampler at Yosemite since March 1988, located at Turtleback Dome. In 2002, improvements to the Sequoia IMPROVE stations added a set of PM10 modules (E &F) at the Ash Mountain site.

Clean Air Status and Trends Network

Clean Air Status and Trends Network (CASTNET) was developed by EPA to monitor dry deposition of gaseous pollutants. By design, monitoring site locations are predominantly rural to assess the relationship between regional pollution and changes in regional patterns in dry deposition. CASTNET also includes measurements of rural ozone and the chemical constituents of PM2.5 (fine particulate matter). Rural monitoring sites of CASTNET provide data where sensitive ecosystems are located and provide insight into natural background levels of pollutants where urban influences are minimal.

These data provide much-needed information to scientists and policy analysts to study and evaluate numerous environmental effects, particularly those caused by regional sources of emissions for which long range transport plays an important role. Measurements from these networks are also important for understanding non-ecological impacts of air pollution such as visibility impairment and damage to materials, particularly those of cultural and historical importance (paraphrased from http://www.epa.gov/castnet).

The CASTNet dry deposition monitoring site located at Lookout Point, within Sequoia National Park, began operating February 1997. The CASTNet site in Yosemite, on Turtleback dome, has been in operation since September 1995.

Light Pollution

Light pollution is not confined to cities. Excessive glare, urban sky glow, and poor lighting threaten dark skies. Night sky visibility is an important aesthetic value of wilderness and its protection has been added to the responsibilities of NPS managers. The objectives of the night visibility monitoring program are to: (1) define the magnitude of night sky brightness, (2) identify short-term or seasonal impairments, (3) utilize monitoring data summaries for public education, and (4) help define limits of acceptable change for night sky visibility.

Dark sky monitoring sites were established in both Sequoia and Kings Canyon. Yosemite currently has one site with a second identified and monitoring began in September 2004.

Natural Soundscapes

Biophony is the combined sound that living organisms produce in a given habitat. When habitat health is stable, indications are that there is a symbiotic and unique relationship between the creature voices denoted by both frequency and time niches discernible on audio spectrogram graphic displays with a high degree of discrimination and detail (Krause 2001). Manmade noise can be harmfully disruptive and, as such, NPS has designated natural soundscapes as a resource, which means they must be protected (akin to "clean air"). The program is managed by the NPS-ARD and parks locally facilitate and conduct sound measurements.

In 2001, Sequoia National Park became the site of a natural soundscape monitoring pilot program. Dr.Bernie Krause and Dr. Stuart Gage collected recordings in different habitats at different seasons to test biophony as an indicator of habitat fitness.

Monitoring and Research Needs

Data Acquisition and Analysis, Monitoring

Current monitoring efforts need to continue. In addition to monitoring efforts, resources should also be devoted to acquiring and integrating existing data, and to analyze and present findings from the available datasets. Existing meteorological and air-quality data could be more extensively analyzed to better characterize patterns of transport of air pollutants (e.g., fine particulate), including the nature of upslope and downslope flows.

Better characterization of pollutant transport is also needed to support the parks' fire management programs, help discern origins of specific pollutants, and provide critical information to complement biological effects research.

Another research and monitoring gap is regarding the prevalence, concentration, and spatial distribution of the nitrogenous ozone precursors that can deposit to low productivity watersheds (discussed below) and change their N cycling regime, and the ecology that depends on it.

Additional efforts should be devoted to characterizing the ambient atmospheric levels of non-criteria air pollutants (e.g., pesticides and gaseous nitrogen) and comparing these levels with their concentrations in aquatic systems. This research effort would be enhanced by linking it to any ongoing studies of atmospheric transport and biological effects.

Wet and Dry Deposition

Continued monitoring of wet and dry deposition is needed to provide estimates of spatial patterns and temporal variability of deposition. The long-term data records should be maintained by continuing wet-deposition monitoring at Giant Forest (NADP). Dry deposition monitoring should continue at Ash Mountain (IMPROVE), and Lookout Point (CASTNet). It is recommended that wet deposition monitoring be reinitiated at Ash Mountain in Sequoia National Park.

The long-term deposition record presently available lends itself to analyses of trends. The data should be analyzed to determine the statistical power of trend tests (i.e., the length of monitoring needed to detect trends and the levels of change that can be discerned within a specified time).

Increased input of nitrogen (i.e., HNO_3, NH_4, NH_3, NO_3) is recognized as an additional stressor to Sierra Nevada ecosystems. There are potential landscape-scale changes such as terrestrial fertilization and aquatic eutrophication due to increased nitrogen and phosphorus loading (Sickman et al. and Fenn et al.) Improved measurements of both wet and dry forms of nitrogen will give more accurate levels of nutrient loading to Sierra Nevada ecosystems

Additional benefit to understanding pollutant levels in the Sierra Nevada would be use of NOx analyzers. Co-location with ozone, wet deposition, and particulate matter would be useful to park management needs, including but not limited to fire operations, health advisories, and monitoring vegetation stressors. Retention of the NOx measurement recently moved to Turtleback Dome should be considered for these purposes, since it provides an indicator of the NOx transported from the Central Valley via the Merced River Canyon into Yosemite.

Ozone

Continuous measurements of ozone are needed to provide estimates of spatial patterns and temporal variability. The long-term data records should be maintained by continuing ozone monitoring at the existing sites at Giant Forest, Ash Mountain, and Lookout Point in Sequoia, and at Turtleback Dome in Yosemite. An ozone monitor was installed in Yosemite Valley to provide information to an ozone effects study in 2001. The study found significant differences in ozone levels between the Valley site and Turtleback Dome. With the high visitation found in the Valley, this site should be retained and added to the NPS ozone monitoring network.

Passive ozone monitors suggest that ozone levels vary significantly within Sierra Nevada parks. Additional efforts to characterize the spatial patterns of ozone concentrations should be supported. Summary statistics documenting violations of the state and federal ozone standards are also of interest. The use of existing passive sampler data should be continued to provide on-site data relevant for co-located ozone-injury vegetation plots. The value of previous ozone data collected with passive samplers should be assessed for developing calibrated spatial relationships relative to analyzers, so that large-scale ozone exposure in the park can be quantified. If the spatial distribution (especially variation in elevation) has not been sufficient, it is recommended that a one-time study with well-distributed passive samplers be used for spatial calibration.

Particulate Matter/Visibility

IMPROVE aerosol monitoring should continue at Sequoia and Yosemite. As part of the IMPROVE Network expansion, the EPA and NPS have upgraded the aerosol sampler in Sequoia to include 2 additional modules for PM10. While the site at Ash Mountain (550 m) serves the purpose of measuring what PM is traveling into the park via the Kaweah River drainage, it inadequately represents the average elevation of the parks. An additional site has been proposed, to be located at a higher elevation (2,250 m). This new location may better represent conditions for the high elevation landscape that dominates the Sierra Nevada. Aerosol concentrations can vary at different elevations throughout the parks. Aerosol and optical monitoring at both high and low elevations would provide information concerning the extent and nature of visibility impairment at Sierra Nevada parks. Emissions from industrial processes and wildland fires also contribute to visibility impairment in all SIEN parks. In addition to monitoring for human health concerns, monitoring should be developed to identify carbon emissions from industrial processes and wildland fires.

Visibility as measured by transmissometers is being utilized in Yosemite. The transmissometer receiver is located on Turtleback Dome with the target transmitter at Foresta. Additional visibility data should be considered in high visitation areas where broad vistas are a hallmark for their respective parks to measure degradation or improvement.

Natural Soundscapes

Natural sound monitoring should be developed for one or more of the SIEN parks. Co-location with a year round air monitoring site would be the most useful as sound levels could correspond with meteorology and various high air pollution events (e.g., high levels of particulate matter or ozone). It would also be logistically practical as the air monitoring sites are visited on a weekly basis.

Dark Sky

The NPS Dark Sky monitoring program is widespread and growing. Yosemite, Sequoia and Kings Canyon have areas targeted for repeat dark sky photography. Comparisons should be made between natural dark sky and light pollution often found in developed areas. This would help in guiding park operations in types and location of light fixtures and could provide information useful to lighting policy and planning for local communities.

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